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Miniscrew Assisted Rapid Palatal Expander (MARPE) as an Adjunct to Orthodontic Treatment

A research submitted to the department of Orthodontics, in the Faculty of Dentistry, Babylon University as a partial requirement of degree of bachelors (B.D.S.)

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اهداء

الحمد لله رب العالمين و الصلاة والسلام على اشرف الخلق اجمعين سيدنا محمد و على اله الطاهرين. بعد ان اكرمنا الله بإتمام هذا البحث يطيب لنا ان نتوجه بالشكر الى الدكتور المشرف (م.م. اميمة لطيف سلمان ، م.م. نورا حسين علي الجنابي) خلف ما قدمه لنا من جهد علمي بناء كان له الاثر في ارساء دعائم البحث و التي كان لها الدور الاساس في اكماله.

كما و نتقدم بالشكر و العرفان لمن منحنا تفاني و التضحيه و الدعاء ورعاية من عوائلنا الكريمة التي صبرت على تحمل اعباء الدراسة و مشاقها و تذليل الصعوبات لنا.

و شكرنا و تقديرنا لجميع من قام بتقديم المساعدات من التدريسيين ،الموظفين و الطلاب و الزملاء وكل من مد يد العون و المساعدة و لو بكلمة و نسأل الله العلي القدير ان يوفق الجميع.

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Introduction

Transverse maxillomandibular discrepancies are a major component of several malocclusions. Previous studies indicate the prevalence of maxillary transverse skeletal discrepancies ranges between 8-22% in different populations [1]. Maxillary expansion is the main treatment option for the management of maxillary transverse skeletal discrepancies (MTD) and posterior crossbite successfully [2]. Rapid Maxillary Expansion (RME) was found to generate forces that exceed the limits of orthodontic tooth movement; which in turn affects the nasomaxillary sutures and increase the transverse width of the maxilla through the opening of the mid-palatal suture (MPS) [3].

Orthopedic and orthodontic forces are used routinely to correct MTD in a young patient. Correction of MTD in a skeletally mature patient is more challenging because of changes in the osseous articulations of the maxilla with the adjoining bones (4). Palatal expansion in a younger age group results in mainly skeletal expansion with opening of the mid-palatine suture (MPS), and a small amount of bone bending and dental tipping. In patients presenting after their peak growth and late in their teens or early twenties, studies shown the rapid palatal expansion have skeletal suture opening, however more dentoalveolar effects occur, and usually only successful cases are reported tipping.

Surgically assisted rapid palatal expansion (SARPE) has gradually gained popularity as a treatment option to correct MTD. It allows clinicians to achieve effective maxillary expansion in a skeletally mature patient. The use of SARPE to treat MTD decreases unwanted effects of orthopedic or orthodontic expansion [4].

With the introduction of mini-implants into the orthodontic armamentarium in the 1980's, the orthodontists' ability to correct skeletal and dental discrepancies, without surgical intervention, has greatly improved.

In the recent times, Miniscrew-assisted rapid palatal expanders (MARPE) have been proposed as an effective non-surgical and non extraction treatment approach for expanding and reduced the need for SARPE in some clinical cases[5].

MARPE appliance consists of an expansion screw anchored to miniscrews (mini-implants) obtained anchorage from the palatal bone [6].

There are different designs of MARPE appliances, i)Bone-anchored expansion appliances (BA), ii) Bone and tooth-anchored expansion appliances (BTA) also known as hybrid appliances. Bone- anchored appliances are designed with the expansion appliances anchored only to the TADs, whereas bone and tooth anchored appliances derive anchorage from both palatal bone and maxillary molars and/or premolars[7] .

Aim of study

To demonstrates that the careful design and application of the MARPE appliance can achieve successful transverse expansion of the maxilla and the surrounding structures in patients beyond the age typically considered acceptable for traditional RME, by confining the transverse forces of the appliance to the MPS and minimizes dental side effects; thus, making them suitable for use in older patients.

Chapter One
Review of Literature

1.1 Arch expansion

Maxillary expansion treatments have been used for more than a century to correct maxillary transverse deficiency. The earliest common cited report is that of E.C. Angell published in *Dental Cosmos* in 1860.[8]

The work was discredited at the time, but the technique is now generally accepted as a relatively simple and predictable orthodontic therapy. Correction of the transverse discrepancy usually requires expansion of the palate by a combination of orthopedic and orthodontic tooth movements. The expansion treatment can be classified into three modalities are: rapid maxillary expansion (RME), slow maxillary expansion (SME) and surgically assisted maxillary expansion. Since each treatment modality has advantages and disadvantages, controversy regarding the use of each exists. Practitioners select treatment appliances based on their personal experiences and on the patient's age and malocclusion [9].

The design of RME can be divided into two main categories: i) Toothborne appliances, and ii) Tooth-tissue borne appliances. The tooth-borne appliances such as Hyrax appliance are designed with the expander connecting with the first molars and often the first premolars. There is no coverage of the palatal tissue with tooth-borne appliances which makes it easier to clean and more hygienic. The tooth-tissue borne expander were designed by Dr. Andrew Hass and in this design the expander covers the palatal tissue with acrylic while connecting with the molars and premolars bilaterally[8] The hypothesis and the proposed rationale for the palatal coverage was that when the expansion screw is activated, the expansion force is distributed on the palatal tissues which allows the adaptation and the remodeling of the palate. Thus, Dr. Hass proposed that this led to more skeletal or orthopedic expansion than tooth-borne expanders[10]

Normal palatal growth is nearly complete by age 6 [11], and increasing interdigitation of the suture makes separation difficult to achieve after puberty. During treatment, transverse forces tip the buccal segments laterally and with proper appliance design, 3rd-order moments will induce bodily translation. If the force is strong enough, separation occurs at the maxillary suture. The clinical conditions indicating maxillary expansion include crossbites, distal molar movement, functional appliance treatment, surgical cases for instance arch coordination or bone grafts, to aid maxillary protraction and mild crowding [9]

1.2 Treatment Modalities

Treatment modalities currently used for correction of maxillary transverse deficiencies are :(12,13)

1.2.1 Rapid Maxillary Expansion (RME)

Rapid maxillary expansion was first described by Emerson Angell in 1860 and later repopularized by Haas. The main object of RME is to correct maxillary arch narrowness but its effects are not limited to the maxilla as it is associated with 10 bones in the face and head. Advocates of rapid maxillary expansion believe that it results in minimum dental movement (tipping) and maximum skeletal movement. When heavy and rapid forces are applied to the posterior teeth, there is not enough time for tooth movement to occur and the forces are transferred to the sutures. When the force delivered by the appliance exceeds the limit needed for orthodontic tooth movement and sutural resistance, the sutures open up while the teeth move only minimally relative to their supporting bone. The appliance compresses the periodontal ligament, bends the alveolar process, tips the anchor teeth, and gradually opens the midpalatal suture and all the other maxillary sutures [9] .

1.2.2 Slow Maxillary Expansion (SME)

SME procedures produce less tissue resistance around the circummaxillary structures and, therefore improve bone formation in the intermaxillary suture, which theoretically should eliminate or reduce the limitations of RME. Slow expansion has been found to promote greater post-expansion stability, if given an adequate retention period. It delivers a constant physiologic force until the required expansion is obtained. The appliance is light and comfortable enough to be kept in place for sufficient retention of the expansion. Prefabrication eliminates extra appointments for impressions and the time and expense of laboratory fabrication. [9]

For SME, 10 to 20 newtons of force should be applied to the maxillary region only 450 to 900 gm of force is generated, which may be insufficient to separate a progressively maturing suture. Maxillary arch-width increases ranged from 3.8 to 8.7 mm with slow expansion of as much as 1 mm per week using 900 gm of force [14, 15].

1.2.3 Surgical Techniques

The effect of dental arch on the maxillary base diminishes as age advances so, surgically assisted expansion techniques can be considered [9]

Indications of surgical expansion are:[16]

- To widen the arch
- To correct posterior crossbite when large amount (>7 mm) of expansion is required to avoid the potential increased risk of segmental osteotomies.

- To widen the arch following maxillary collapse associated with a cleft palate, in cases with extremely thin and delicate gingival tissue, or presence of significant buccal gingival recession in the canine-bicuspid region of the maxilla; and in condition, where significant nasal stenosis is found.

The techniques available are:

- Surgically assisted rapid palatal expansion (SARPE).[4]
- Segmental maxillary surgery.

Surgically assisted rapid palatal expansion (SARPE) has gradually gained popularity as a treatment option to correct MTD (Maxillary Transverse Deficiency). It allows clinicians to achieve effective maxillary expansion in a skeletally mature patient.

Segmental Maxillary Surgery–transverse expansion can be produced during a Le Fort I osteotomy by creating an additional surgical cut along the midpalatal suture. The maxillary halves are then separated and retained in the new position. The relative inelasticity of the palatal muco-periosteum limits the degree of expansion that may be achieved.

Before surgery, orthodontic treatment involves moving the roots of the maxillary central incisors apart to improve surgical access to the osteotomy site. This is the technique of choice in patients, who require expansion and have coexisting sagittal and/or vertical maxillary discrepancies [9] .

1.3 History of Expansion Appliances

In the late 19th century, significant developments in orthodontic devices and techniques were introduced by various practitioners. Wescott, in 1859, pioneered the application of mechanical forces on the maxillary bones using a telescopic bar and double-clasps to correct a cross bite (**Fig.1**). Angell, a year later, employed a differentially threaded jackscrew for palatal expansion (**Fig. 2**), in two weeks later he noting bone separation evidenced by a gap between central incisors [17] .

In the year 1877, Walter Coffin developed a spring for the purpose of arch expansion, which has come to be known as coffin spring. This spring also produces arch expansion by the separation of MPS, when used in young children patients [17] . .

Goddard, in 1893, standardized palatal expansion, utilizing a device similar to the Hyrax appliance. being attached to the first bicuspids and second molars bilaterally. He activated the device twice a day for 3 weeks. Yet, the RME devices of the time did not gain popularity. Slow expansion devices remained in vogue and it was as late as 1956 when Korkhaus reintroduced the appliance in the United States of America. It was the hard work, with extensive research on animals, that Andrew Haas managed to popularize the rapid maxillary appliance. In the late 1940s, Graber advocated RME for the treatment of cleft lip and palate patients. Since then clinicians have increasingly included RME in the treatment of their patients [19].

Although the main object of RME is to correct maxillary arch and separates the mid palatal suture but its effects are not limited to the maxilla only but also affects the circum-zygomatic and circum-maxillary sutural systems as the maxilla is associated with 10 bones in the face and head [9]

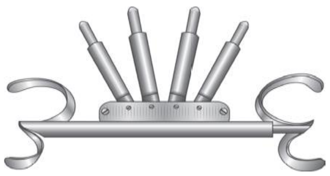


Figure 1 .: Wescott's expansion device

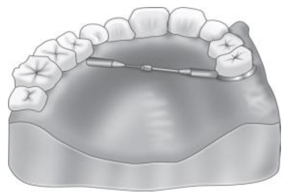


Figure 2 : Angell'spalatal expansion device placed on the maxillary teeth

1.4 Fixed Rapid Maxillary Expansion Appliances

Fixed rapid maxillary expansion appliances are non-removable devices classified into tooth and tooth-tissue borne types. Tooth and tissue borne appliances include the Derichsweiler and Haas types [18]. The Derichsweiler expansion appliance **(Fig. 3)** features molar bands with wire tags soldered into the palatal surface, connected to a jack expansion screw [18]. The Haas expander, popularized in 1961, consists of molar bands, a midline jackscrew, and support wires for increased rigidity **(Fig. 4)**

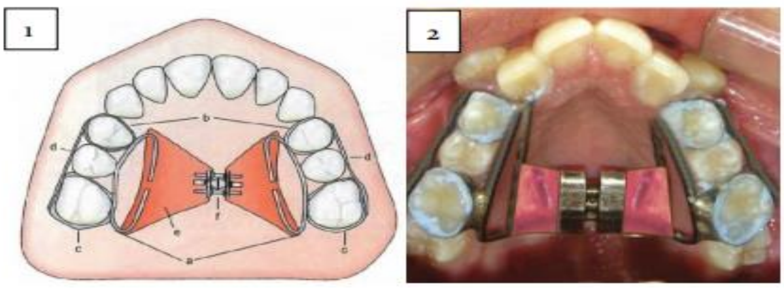


Figure 3: (1) Hass type of expansion appliance, (a) Lingual support wire, (b) Premolar bands, (c) Molar band, (d) Buccal support wire, (e) Acrylic plate, (f) Expansion screw. (2) Hass type of expansion appliance [19]

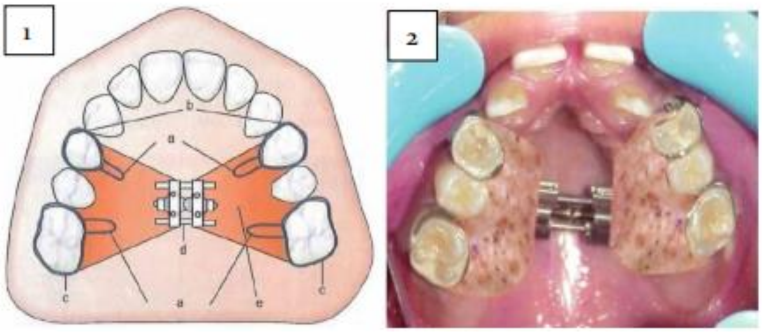


Figure 4: (1) Parts of Derichsweiler expansion appliance, (a) Wire tags, (b) Premolar bands, (c) Molar bands, (d) Expansion screw, (e) Acrylic plate. (2) Derichsweiler type of expansion appliance[19]

The Hyrax-type expander, a commonly used banded rapid maxillary expansion (RME) appliance, is entirely stainless steel and includes bands on maxillary molars and premolars. The expansion screw is localized in the palate, with optional buccal and lingual wires for added rigidity **(Fig.5)** . The Isaacson expansion appliance **(Fig.6)**, a fixed tooth-borne device without acrylic covering, comprises molar and premolar bands with metal flanges and a spring-loaded expansion screw for activation [9,18].

Figure 5. 16.8: Hyrax expander

Figure 6: Isaacson expansion appliances

Bonded rapid maxillary expansion **(Fig. 7)** involves acrylic splints covering maxillary teeth with an attached jack screw. The splint may be a cast cap or acrylic splint, reinforced with a wire framework. These appliances facilitate controlled maxillary expansion, contributing to orthodontic treatment protocols [19] .

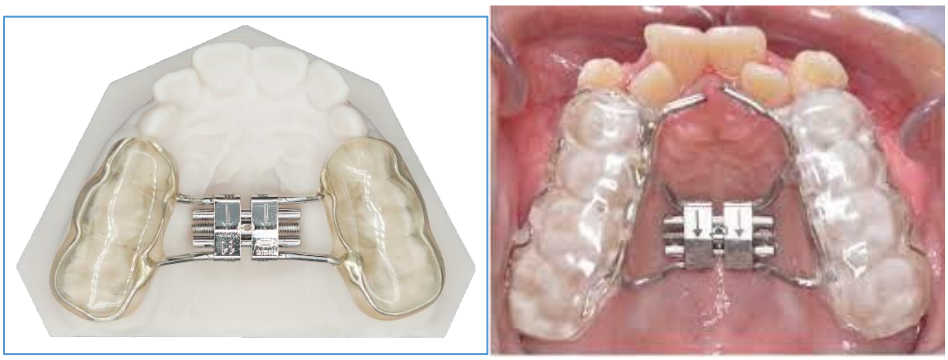


Figure 7: Bonded rapid maxillary expansion appliances

1.4.1 Expansion Screw:

A typical expansion screw consists of an oblong body, divided into two halves. Each half has a threaded inner side that receives one end of a double ended screw. The screw has central bossing with four holes. These holes receive a key called expansion screw key (**Fig. 8/ A and B**) which is used to turn the screw [18]

Figure 8/A and B: (A) Expansion screw key; (B)Showing activation of expansion screw by placing the key in the hole [18]

Various types of expansion screws **(Fig. 9)** are available to carry out different types of expansion [18] as enumerated in **Table 1.**

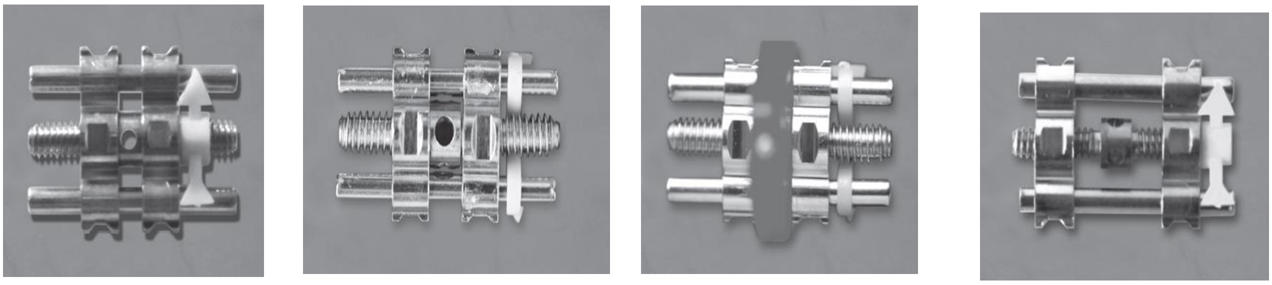


Figure 9: Different types of expansion screws

Table 1: Different types of expansion screws

Expansion screw type	Use
Symmetrical bilateral expansion screw	Bilateral expansion
Traction screw	Closing spaces
Three-dimensional	Anterior and bilateral expansion
Expansion screw with split activator	Separate expansion of maxilla or mandible

1.4.2 Anatomy of Maxilla (Figure 10)

The tenacity of circummaxillary attachments due to buttressing is strong posterosupero-medially and posterosupero laterally A palatine bone forms an intimate relationship with maxilla to form complete hard palate (or) floor of nose and greater part of lateral wall of nasal cavity. It articulates anteriorly with maxilla through transverse palatal sutures and posteriorly through pterygoid process of the sphenoid bone. The interpalatine suture joins the two palatine bones at their horizontal plates and continuous as inter maxillary sutures. These sutures form the junction of three opposing pairs of bones: the premaxillae, maxilla, and the palatine. The entire forms mid-palatal suture [20]

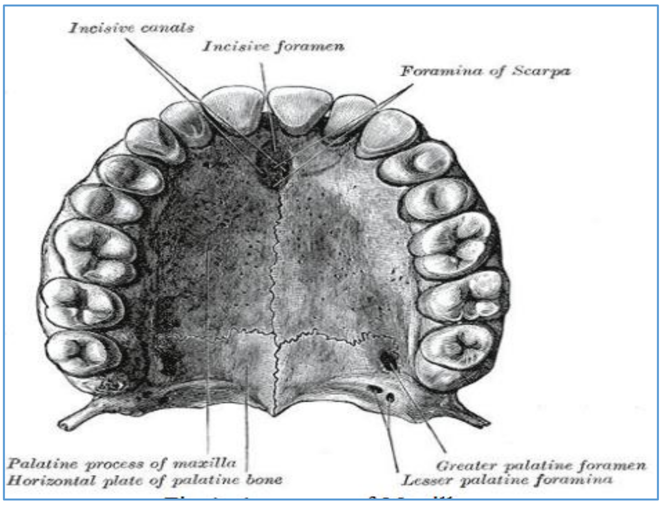


Figure10: Anatomy of Maxilla

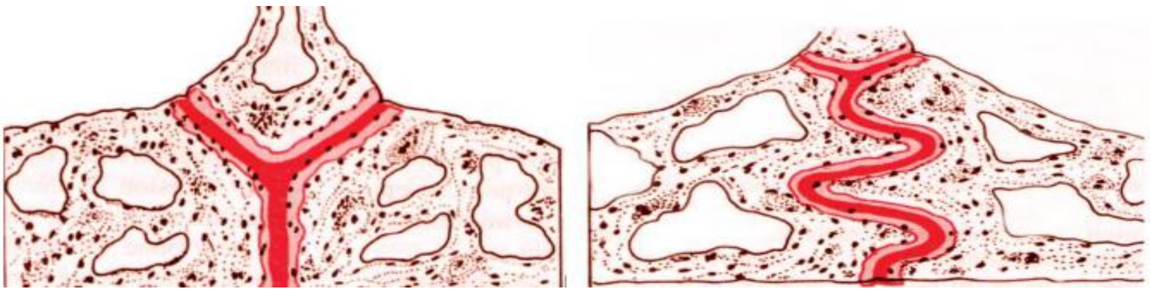
1.4.3 Anatomy of palatal suture

It articulates anteriorly with maxilla through transverse palatal sutures and posteriorly through pterygoid process of the sphenoid bone. The interpalatine suture joins the two palatine bones at their horizontal plates and continuous as inter maxillary sutures. These sutures form the junction of three opposing pairs of bones: the premaxillae, maxilla, and the palatine. The entire forms mid-palatal suture. Mid Palatine suture plays a key role in RME [20,21].

Shape of the suture throughout life is variable as: (**Fig 11**)

- Infancy - Y-shape
- Juvenile - T-shape
- Adolescence –Jigsaw puzzle

As sutural patency is vital to RME, it is important to know when does the suture closes by synostosis and on an average 5% of suture in closed by age 25 yrs. Earliest closure occurs in girls aged 15 yrs10. Greater degree of obliteration occurs posteriorly than anteriorly [20].



Mid palatine suture in infancy

Mid palantine suture in early adolescence

Figure 11: Shape of palatal suture

1.5 Mode of action of RME

Applied to the maxillary posterior teeth. RME usually takes 1 to 4 weeks with an expansion rate of 0.2 to 0.5mm per day. The force from a single turn of jackscrew palatine processes of the maxilla are found to move in a non-parallel shape. It was shown that the amount of suture opening depends on the individual and area of results in proliferation and then suture regeneration and repair. The separating RME occurs when a laterally directed force, over the limits of tooth movement, is the suture. With RME the intermolar width may increase up to 10mm and skeletal changes are usually about 50% of the overall changes. This mechanism leads to separation of the midpalatal suture. Tissue injury was found to be approximately 3 to 10 pounds. Force from RME compresses the periodontal ligament and alveolar processes [22].

1.5.1 Effect of RME on maxillary and mandibular complex

1.5.1.1 Maxillary skeletal effect:

Rapid maxillary expansion occurs when the force applied to the teeth and the maxillary alveolar processes exceed the limits needed for orthodontic tooth movement. The appliance compresses the periodontal ligament, bends the alveolar processes, tips the anchor teeth, and gradually opens the mid-palatal suture [23]

When viewed occlusally, Inoue found that the opening of the midpalatine suture was nonparallel and triangular with maximum opening at incisor region and gradually diminishing towards the posterior part of palate (**Fig.12**). Viewed frontally, the maxillary suture separates supero-inferiorly in a nonparallel manner [24]. It is pyramidal in shape with the base of pyramid located at the oral side of the bone.

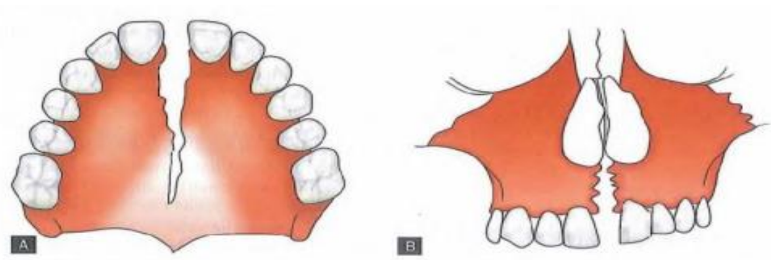


Figure 12: Effect of RME on maxillary skeletal base. RME causes triangular or fan-shaped opening of the MPS with maximum opening in the maxillary incisors region and gradually diminishing towards the posterior part of the palate. (A) Transverse view. (B) Frontal view [18]

1.5.1.2 Maxillary Halves:.

The maxilla was found to be more frequently displaced downward and forward [24] . Haas suggested when the midpalatal suture opens, the maxilla always moves forward and downward [25]. Skeletal changes in vertical and anterior displacement of maxilla with bonded rapid palatal expansion appliances using the lateral cephalograms showed that downward and anterior displacement of the maxilla may be minimized or negated with the use of the bonded appliance [26].

1.5.1.3 Palatal vault:

The palatine processes of the maxilla were lowered as a result of the outward tilting of the maxillary halves, also the palatal vault height decreased significantly during RME. Palatal height returned to pretreatment values one year after expansion and increased an average of 0.5mm two years after treatment [23].

1.5.1.4 Effects of RME on Maxillary anterior teeth: (Fig. 13)

One of the most dramatic changes accompanying rapid expansion is the opening of a diastema. It is estimated that during active suture opening, the incisors separate approximately half the distance the expansion screw has been opened, but the amount of separation between the central incisors should not be used as an indication of the amount of suture separation. This diastema is self-corrective due to elastic recoil of the transeptal fiber [27]

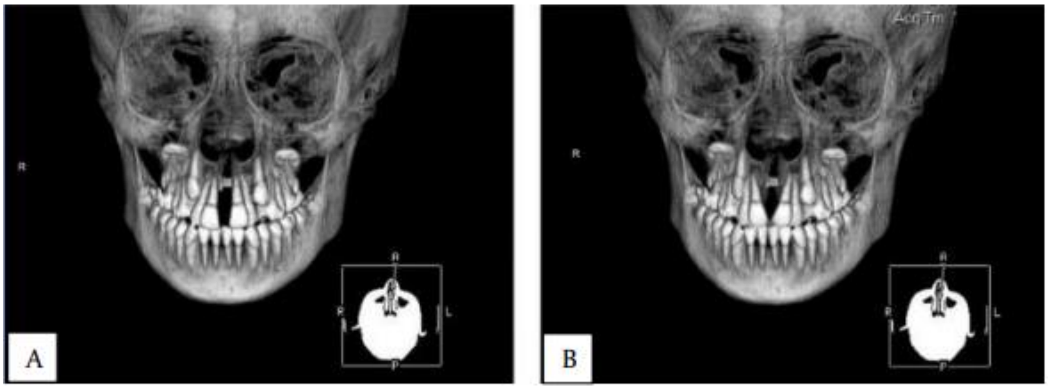


Figure 13 : Effect of RME on maxillary anterior teeth (A) The effect of RME on the MPS, Note the midline diastema, (B) Midline diastema closes within 6 months due to transseptal fiber traction[19]

1.5.1.5 Effects of RME on Maxillary posterior teeth: (Fig. 14)

With the initial alveolar bowing and condensing of the periodontal ligament, there is a certain change in the long axis of the posterior teeth and the angulations of both the sides of molars increased from 1° to 24° during expansion [27]

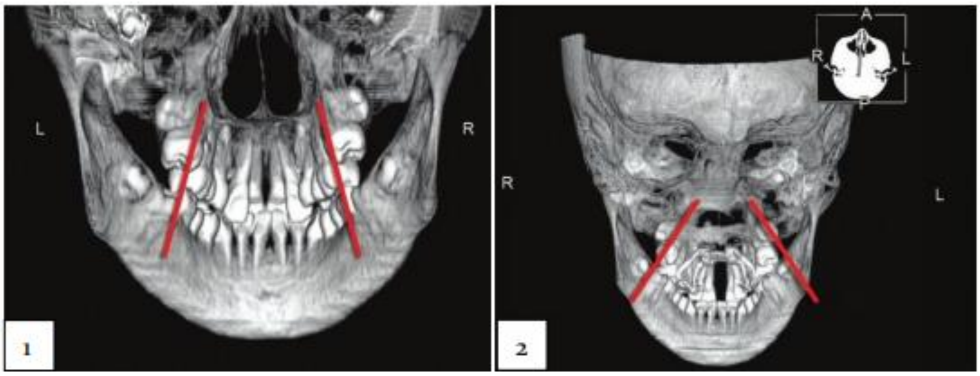


Figure 14: Effect of RME on maxillary posterior teeth, (1) Normal axial inclination of the anchor molars, (2) Buccally tipped anchor molars [19].

1.5.1.6 Effects of RME on the Mandible:

Due to disruption of occlusion caused by extrusion and tipping of maxillary posterior teeth along with alveolar bending there is a tendency for the mandible to swing downward and backward which causes the opening of the mandibular plane [27]. **Fig. 15**

RME could lead to a concurrent expansion of the lower arch as much as 4 mm in inter-canine width and 6 mm in inter-molar width [23]

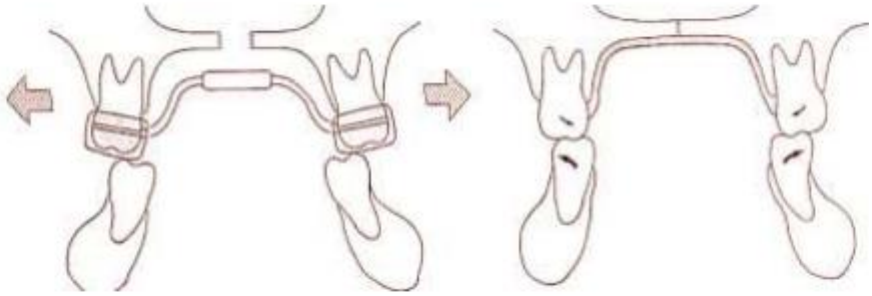


Figure 15: Effect of RME on the mandible

1.5.1.7 Effect of RME on alveolar processes:

Because bone is resilient, lateral bending of the alveolar processes occurs early during RME. Most of the applied forces tend to dissipate within 5 to 6 weeks. After stabilization is terminated, any residual forces in the displaced tissues will act on the alveolar processes resulting in rebound effect [26]

1.5.1.8 Effects of RME on adjacent facial structures:

Kudlick, in a study on a human dry skull that simulated in vivo response of RME, concluded the following: [24]

1. Directly attached bones of craniofacial region were moved except sphenoid bone.
2. No change in cranial base angle.
3. Displacement of the maxillary halves was asymmetric.
4. Sphenoid bone was the main uphold against expansion of maxilla not the zygomatic arch.

1.5.1.9 Effect of RME on nasal cavity:

Anatomically, there is an increase in the width of the nasal cavity immediately following expansion thereby improves in breathing. The nasal cavity width gain averages of 1.9 mm, but can be as wide as 8 to 10 mm [20]

1.5.2 Indications for RME [23]

1. Severe maxillary constriction (narrow maxillary base or wide mandible).
2. Unilateral or bilateral posterior crossbites.
3. Anteroposterior discrepancies.
4. Patients with Class III malocclusions and borderline skeletal an pseudo Class III problems.
5. Cleft lip and palate patients with collapsed maxillae **(Fig. 16).**
6. To gain arch length in patients who have moderate maxillary crowding.

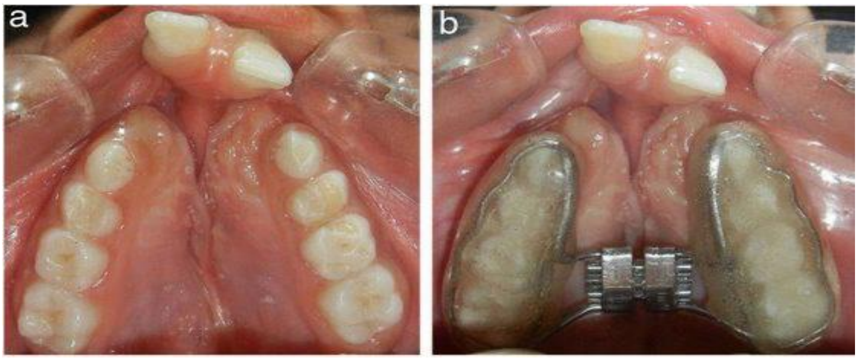


Figure 16: Cleft lip and palate patients with collapsed maxilla**.**

There are other claims of RME use, which have not been investigated sufficiently to conclude an association with so far, these controversial areas are:[23]

A. Improve symptoms of obstructive sleep apnea
B. Reduce nasal airflow resistance.
C. Improve hearing in patients with conductive hearing loss
D. Treating Nocturnal Enuresis.

1.5.3 Contraindications for RME [28]

1. Uncooperative patients.
2. Patients who have anterior open bites.
3. Steep mandibular planes, and convex profiles **(Fig.17).**
4. Single tooth in crossbite.
5. Patients who have skeletal asymmetry of the maxilla or mandible (**Fig. 18).**
6. Adults with severe anteroposterior and vertical skeletal discrepancies.

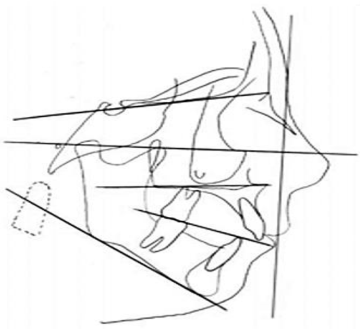


Figure 17: Steep mandibular planes, and convex profiles.

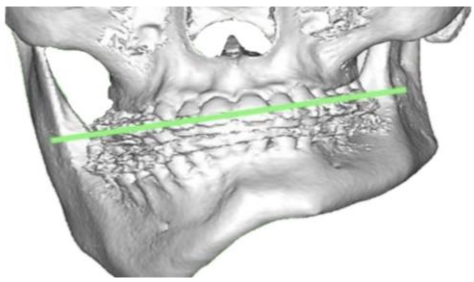


Figure 18: Skeletal asymmetry

1.6 Activation of the RME appliance

The basic principle of the appliance involves the generation of forces that are capable of splitting the MPS. Hence, the forces should be definitely more than the usually used orthodontic forces. The forces generated are close to 10 to 20 pounds. An expansion of 0.2 to 0.5 mm achieved per day. The screw is activated at between 0.5 to 1 mm per day and about 1 cm of expansion can be expected in 2 to 3 weeks. The activation schedules tend to vary depending upon the age of the patient and form of the appliance [19] . Zimring and Isaacson [32] recommended, two turns per day for initial 4-5 days followed by one turn per day in growing individuals. For adults the recommended two turns each for the first two days followed by one turn per day for the next 5-7 days and then only one turn every alternate day till the desired expansion is achieved. Surgery can be used as an adjunct to RME therapy in adult patients, especially in the third decade of life or later [19].

1.7 Retention followed by RME

The retention period is the last factor that affects the expansion achievers by RME. Retention is necessary to prevent relapse and to allow the new bone formation to consolidate. Retention can be achieved by using the same appliance as a passive retainer

after immobilizing the screw using cold cure acrylic (**Fig. 19)** or by using a different appliance, such as using a transpalatal arch. The duration of the retention period varies depending on the age of the patient, the amount of expansion, and the type of appliance. Generally, the retention period should be at least as long as the active expansion period, and preferably longer. Some studies suggest that the retention period should be 3 to 6 months for rapid expansion, 6 to 12 months for slow expansion, and 4 to 8 months for semi-rapid expansion[29,30,31]

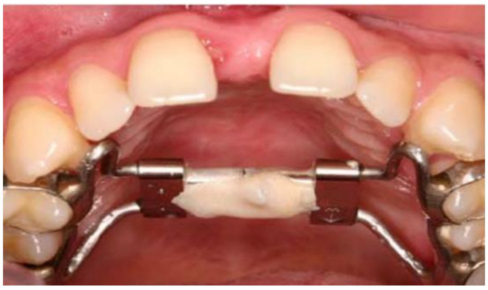


Figure 19 : Retention period with the Hyrax device. The appliance is covered with acrylic

1.8 Miniscrew Assisted Rapid Palatal Expansion (MARPE)

1.8.1 Introduction:

In recent years, Miniscrew or microimplant-assisted rapid palatal expansion (MARPE) has positioned itself as a non-surgical alternative and to avoid multiple surgeries , nonsurgical maxillary expansion was performed with the MARPE to achieve both skeletal and dentoalveolar expansion for transverse correction . It is reported to be an effective treatment for maxillary expansion in patients from the age of 16 onwards (success rate: 92.5%) [33] .

MARPE is a simple modification of the conventional RME appliance (**Fig. 20**); the main difference is the incorporation of several miniscrews to ensure expansion of the underlying basal bone and maintain the separated bones during the consolidation period [34].

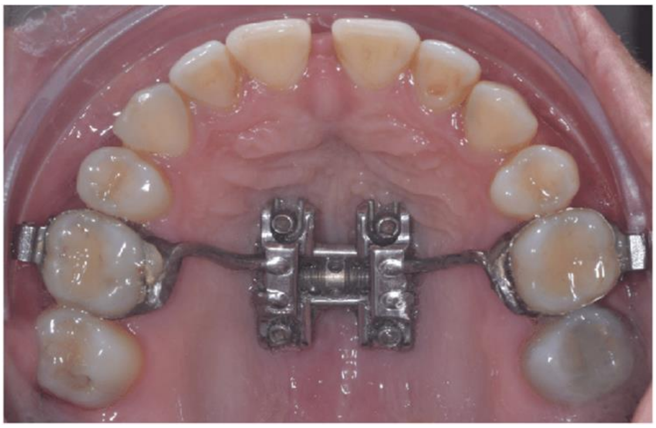


Figure 20: Miniscrew assisted rapid palatal expansion (MARPE)

The concept of miniscrew assisted rapid palatal expansion (MARPE) emerged more than a decade ago. In the MARPE designs, miniscrews substitute teeth as the main anchorage receiving the expansion force and transfer the force to the underlying skeletal structures and hold the positions of the two expanded maxillary halves during the bony bridging of the two segments. [35, 36]

MARPE was first introduced by Lee et al. (2010) [35], he reported successful expansion of the maxilla through opening of the MPS. The incorporation of micro-implants into the palatal jackscrew ensures expansion of the palate with minimal damage to teeth and periodontium, with stable outcomes confirmed by clinical and radiographic examination thus minimizing unwanted dentoalveolar effects such as tipping and expansion. The authors concluded that it is an effective treatment modality used for transverse correction and which might eliminate the need for a few surgical procedures in patients with craniofacial discrepancies, thus taking advantage of the possibilities offered by the sutures.

In MARPE, the mini-implants are used to fixate the expansion appliance to the maxillary palatal bones. A force is generated when the expansion screw is turned, which then passes to the mini-implants, and then to the palatal bone, which lies adjacent to the

MPS. This force thereby acts to break open the interdigitation of the MPS between the maxillary palatal bones [37]

Various designs have been recommended by many authors [38, 39] without any dental support (exclusively bone borne), with support from teeth (teeth-bone borne) and two/four mini screws [40]. Stress distribution trajectories are mainly along three buttresses in the maxilla; namely zygomaticomaxillary, nasomaxillary and pterygomaxillary. Thus, MARPE appliance is beneficial in adult patients with more sutural resistance to skeletal expansion and even in young patients by minimizing or even preventing dental tipping thus avoiding further increase in the vertical dimension and other aforementioned side effects [41].

The disadvantages of MARPE are the difficulty in keeping the area clean, the invasiveness of the micro-implants, and the increased risk of infection [42]

1.8.2 Selection and Location of Expander and Screw

The selected expander should be the one with the greatest expansion capacity that, at the same time, may be kept at an ideal vertical distance from the palatal mucosa. Bicortical anchorage (oral and nasal) is determinant of success and if the expander is too distant from the mucosa (more than 2 mm), Micro implants (MI) may not reach the nasal cortical bone. Moreover, chances of MI deformation are higher if the force is applied too far from the implant/bone interface .

The body of the expander should be placed as posterior as possible, close to the junction of hard and soft palate (hard palate mucosa is whiter) .The greatest resistance against suture opening is located in the sutures between maxilla and pterygoid plates and forces should be applied more posteriorly to overcome initial resistance and promote parallel opening of the midpalatal suture [43, 44]. (Fig. 21)

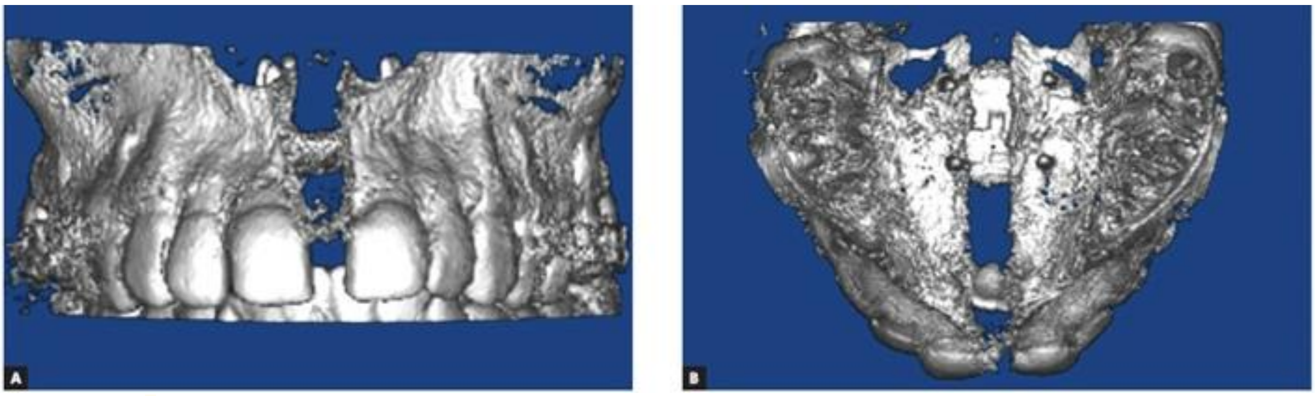


Figure 21: When expander is placed at a more posterior position, forces concentrate closer to the pterygoid plates, structures that offer great resistance to palatal expansion. Therefore, occurs a parallel opening of the palatine suture anteroposteriorly and vertically, differently from conventional expansion, in which opening takes the form of a "V" (broader in anterior region).

When forces are applied directly into the center of resistance of the maxilla by means of MI, and not to teeth (as in conventional expansion), the force system is more favorable due to a homogeneous force dissipation, which prevents buccal tipping and produces a more parallel suture opening. [45] (Fig. 22)

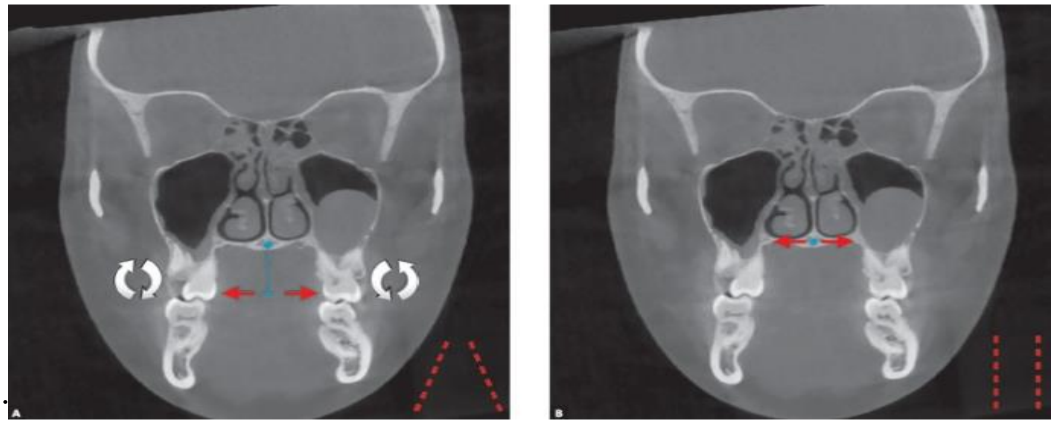


Figure 22: In conventional palatal expansion, forces are applied to teeth, below the center of resistance of the maxilla. This system of forces generates buccal dentoalveolar tipping and an inverted-V opening (coronal view), indicated by the red dotted lines\ B) in MARPE, forces are applied directly into the maxillary center of resistance by means of the MI, which practically eliminates inclination forces of posterior teeth and promotes more parallel suture opening in a coronal view (indicated by red dotted lines)

Dimensions of mini screws as per the design of appliance i.e., 2 implant or 4 implant design. The length of implant chosen should consider height of insertion slot, space between the appliance and palate, thickness of palatal mucosa and a desired minimum of 5-7mm of bone engagement. Intention should be to achieve bi-cortical engagement aiding for better stability of mini screws.

1.8.3 Different Designs of Expanders using microimplants

Following are the different designs of expander using microimplants (**Fig 23)**

Type 1: Bone-borne expander with microimplants placed lateral to midpalatal suture
Type 2: Bone-borne expander with microimplants placed at the palatal slope
Type 3: Miniscrews as in type 1 but with additional conventional Hyrax arms

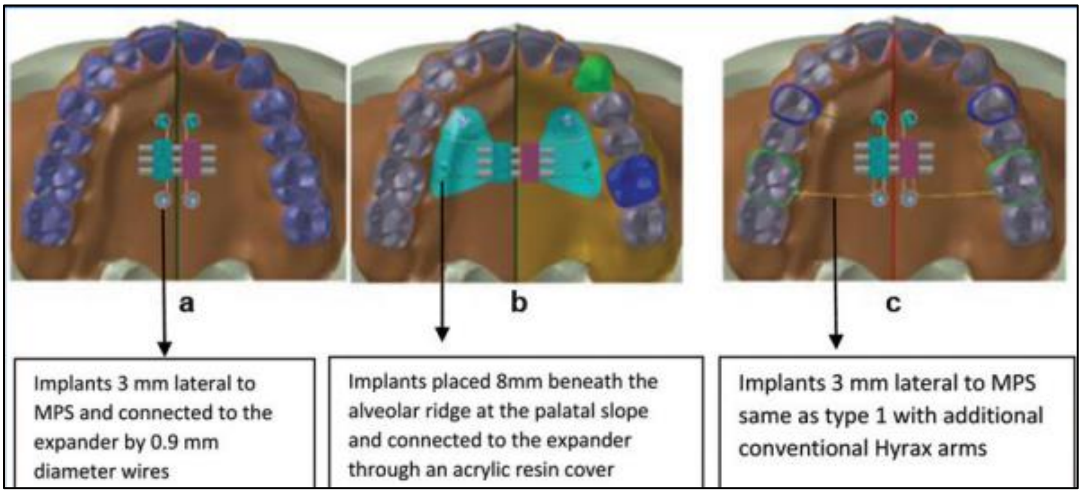


Figure 23: Designs of the RME types using microimplants: (A) Type 1, (B) Type 2, (C) Type 3

1.8.4 Insertion technique

A small amount of anesthetics (no more than 1/4 of a cartridge) may be applied only once on each side, between the two ipsilateral MI. Anesthetic application local should be carefully chosen, and the needle should always be placed close to the midpalatal suture to avoid contact with the palatine artery. The operator should have extensive knowledge of the position of this artery, which may vary according to palate depth.[46] Whenever possible, a vasoconstrictor combined with the anesthetic should be used to reduce bleeding, which is often absent.

Micro implant (MI) should be placed carefully, although the guides (expander holes) facilitates its placement. Micro implant should be as perpendicular as possible to the palatal bone (each MI parallel to all others) so that the force distribution is effective. Therefore, both the anteroposterior and the lateral inclination should be repeatedly checked during placement. When placing the posterior MI, patient should keep the mouth wide open to avoid changing their anteroposterior inclination (MI tend to distal tipping). MI can be delivered in most patients without previous bone perforation, using the digital key. If torque is excessively high, bone perforation can be made using a 1 mm diameter drill.[44]

Concerning the type of insertion of miniscrews, the bicortical insertion is recommended, particularly with anchorage in internal cortical plates of the palate and nasal fossa. The fixation in both cortical plates is fundamental to aid the anchorage during expansion and to surpass the resistance of maxillary bones to separation. When the monocortical insertion of miniscrews is used in individuals with thick suture or with great resistance to maxillary separation, distortions or folds may occur in the temporary anchorage device during activation of the expanding screw . Therefore, a correct selection of minscrew length by analysis of bone tissue thickness and height of midpalatal suture, assessed by CBCT examination, is relevant for the success of MARPE.[47]

1.8.5 Activation Protocol

The activation protocol varies based on the treatment objective and patient biotype. Activation schedule guidelines (Table 2) should be followed for better treatment progress. On an average, 0.2mm of separation is achieved per turn. In adults, activation may be reduced to once a day after interincisor space appears. Activation is terminated when an edge to edge contact is achieved between the lingual cusps of maxillary first molars and the buccal cusps of the mandibular first molar. The authors recommend giving the patient a paper form to control activations. The 8 mm MSE has 40 activations (0.2 mm per turn); the 10 mm one, 50 activations; and the 12 mm one, 60 activations. Activations should not reach the limit, because the expander loses rigidity as it approaches the limit and might undergo some deformation[44]

Table 2: Suggested activation protocol

Age Group	Initial Expansion Rate	Expansion After Opening MPS (Diastema For-mation
Beginning of adolescence(13-16 years)	3-4 turns/week	3 turns/week
End of adolescence (16-19 years)	1 turn /day	1 turn/day
Young adult (19-25 years)	2 turn per day	1 turn/day
Adult (older than 25 years)	2 or more turn per day	1 turn/day

1.8.6 Treatment Objectives

The treatment objectives were to as follows [41]

1. To correct transverse maxillary deficiency
2. To maximizing skeletal expansion
3. To minimizing buccal tipping
4. To establish acceptable buccal occlusion and
5. To maintain sound periodontal and bone support.

1.8.7 Post-expansion assessment

Occlusal radiographs or CBCT should be requested to confirm MARPE success, defined by midpalatal suture opening, because not all cases display an interincisal diastema. However, if the diastema is created, as in the case here reported, suture split and skeletal expansion of the maxilla are evident. It remains unclear why few MARPE cases fail, but it is believed that differences in calcification patterns of the midpalatal suture and craniofacial architecture (higher resistance) are contributing factors.[35,48]

A retrospective study showed that the mid palatal suture opening efficiency (ratio of expansion screw opening to suture separation) for MARPE was 71% and 63% in the anterior and posterior, respectively [35,47] reported that maxillary skeletal expansion accounted for 37%, whereas alveolar expansion accounted for 22% of total expansion gained by MARPE. These ratios are higher than those of the conventional RPE, which indicates that MARPE promotes skeletal changes.

As mechanical forces are distributed into the palate by the miniscrews, the stress on teeth and supporting structures is understated, which might reduce side effects such as gingival recession and buccal bone dehiscence.[34,49,50] . A clinical study that followed up

69 young adults that underwent MARPE did not find any clinically significant side effects

Other studies of conventional palatal expansion in young adults without MI's have warned about the risk of side effects.[51] Lin et al. [52] recently conducted a direct comparison of MARPE and conventional expansion (mean age 18.1 ± 4.4 years) and found that MARPE was more orthopedically efficient and had a lower rate of dentoalveolar side effects. This initial data may be suggestive of evidence, which should be further investigated in randomized clinical trials

No severe complications of MARPE have been reported in the literature. The most frequent complication is the inflammation and hyperplasia of the mucosa around the MI, usually associated with inadequate local hygiene. A significant amount of time should be spent to orientate the patient about hygiene importance, using all the tools to optimize it (dental brush and water jet). In cases where mechanical control is not sufficient, a chemical method can be temporarily employed (usually chlorhexidine rinse or gel) [44]

1.8.8 Laboratory and Clinical Procedures

Laboratory and clinical procedures of the MARPE is similar to that of a conventional Hyrax expander. The steps below should be followed [44] :

First visit: Thorough explanation of procedures to the patient, clarifying all details and technical limitations and reasserting that failure may occur; placement of separator elastics on the permanent maxillary first molars.

Second visit : Removal of separators, prophylaxis and band placement on first molars; conventional alginate transfer impression; regular plaster pouring; separators elastics placed again on molars; orthodontic accessories (tubes and brackets) may be soldered to the bands at this stage.

Laboratory procedures (**Fig. 23**): Selection of 8, 10 or 12 mm MSE according to palate width (details below); bending wires to reach the bands, following palate curvature, at a separation of at least 2 mm along all their extension; wire soldering to the bands, followed by finishing and polishing; reverse traction hooks may be soldered to the buccal aspect of bands at this stage.

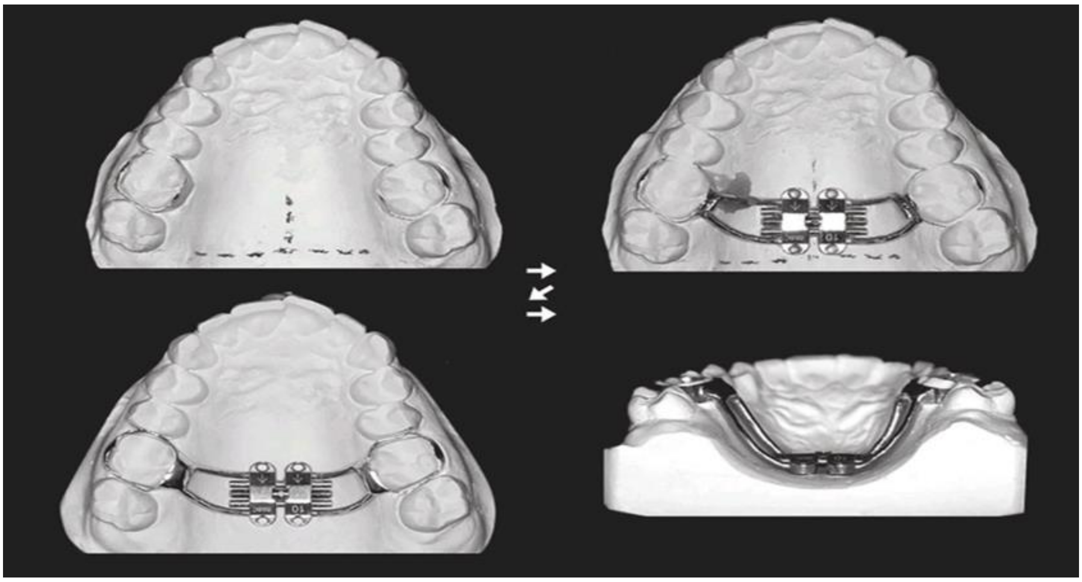


Figure 24: The laboratory manufacture of the MSE appliance, the posterior view shows that expander is flush to palatal mucosa, but should not touch it [44]

Third visit (Fig 2): Removal of separators, prophylaxis and expander proof; application of topical anesthetics to the palate; appliance cementing, checking the vertical position in relation to palate; local infiltrative anesthesia; self-drilling microimplant placement using appropriate digital key (Biomaterials Korea ®, Seoul, South Korea); immediate expander activation (2 to 3 turns); instructions about hygiene and activation; prescription of analgesic drug of choice for two days (optional); no need for antibiotic coverage if the patient has good general health.

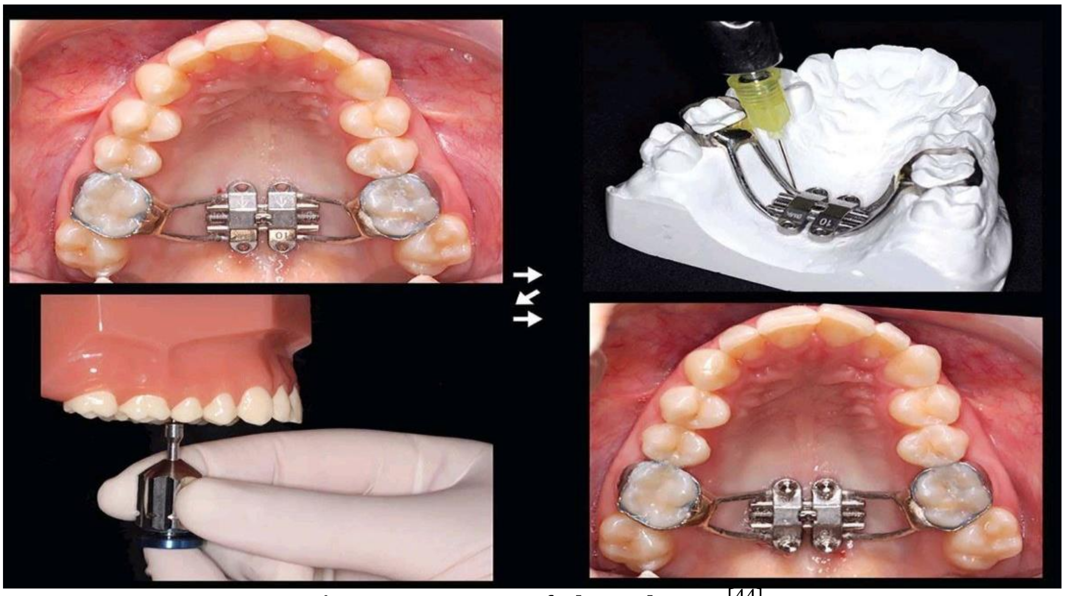


Figure 25: Steps of clinical visit [44]

Follow-up: The patient should be seen more often than in conventional expansion. In some cases, the patient is not able to activate the expander at home due to increased resistance, and the professional support is necessary. At all visits, the distance of the expander from the mucosa should be checked. In case of contact, tissue inflammation develops rapidly compromising appliance removal [38]. The stability of all MI should be checked regularly using tweezers and, in case any mobility is found, MI should be removed; the treatment may continue, although extra carefully, even if there is only one MI on each side. [48]

Removal:

For removal, the same connector used for placement, coupled with the digital key, should be slowly turned counterclockwise. Plaque may accumulate on the MI head, which hinders MI gripping (careful previous cleaning of the site is required). Due to the forces applied, MI tipping may occur and complicate the gripping. In most cases, the MI may be removed without anesthesia. Immediately after each MI is removed, a cotton pellet soaked in hydrogen peroxide might be applied to the site to promote asepsis, but no additional care is required. Mucosa wounds usually heal in two to three days after removal. MI should be discarded after removal, and should never be sterilized or reused[44].

1.9 Latest technological advancements:

A surgical guide is an essential tool that gives three dimensional (3D) orientation for accurately placing implants at the correct depth and proper angle of insertion in the bone. A 3D template preparation needs preoperative planning based on volumetric tomography and customised software [53]. Maino et al.[54] introduced a new high precision 3D miniscrew insertion guide system called Miniscrew Assisted Palatal Appliance (MAPA) system.

The CBCT and intraoral scan of the dental arches are an aid to MAPA guide. Standard Triangulation Language (STL) files obtained from intraoral scans of the patient were superimposed onto the Digital Imaging and Communications in Medicine (DICOM) files of the CBCT scan. The thicknesses of the palatal bone were accessed, and the ideal positions for four virtual miniscrews were identified. A 3D template was then designed and printed three dimensionally. [53]

Maino et al. [54] introduced Tandem Skeletal Expander (TSE) which comprises two expansion screws, mounted on four 11×2 mm spider miniscrews. A 3D surgical guide was prepared and then printed using the MAPA System. Parallel opening of the mid palatal suture was achieved when simultaneously activating both the screws due to equivalent anterior and posterior increases in the transverse dimension. The 3D technological processes assure efficient, accurate, and predictable orthodontic planning, since they standardise the technique and reduce the risks.

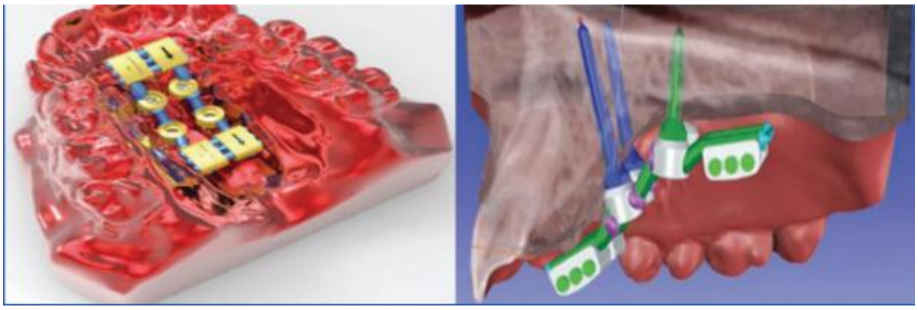


Figure 26: Digital occlusal and sagittal views of Tandem Skeletal Expander and miniscrews[53]

Graf et al.[55] used CAD-CAM technology to custom fabricate metallic mini-implant supported appliances with direct 3D metal printing via laser melting and laser welding of the hybrid hyrax. (**Fig 26**)

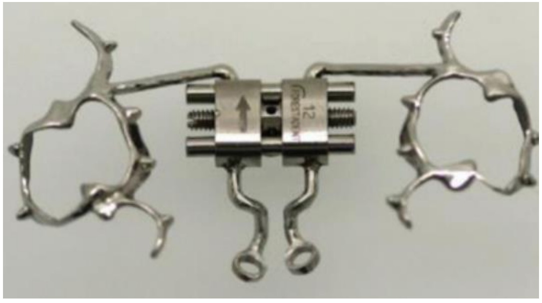


Figure 27: Laser printed hybrid hyrax expander[53]

1.10 Limitations of MARPE[53]

1. The most frequent complication is the inflammation and hyperplasia of the mucosa around the mini-implant
2. In the tooth-bone-anchored design of MARPE appliance, a significant amount of dental tipping was reported in few studies due to the thickness of the connecting arms which is soldered to the molar bands
3. Unilateral expansion is not feasible in basic MARPE design, modifications are required
4. Reduced or absent bone thickness, contraindicates MARPE placement
5. Systemic conditions like type II diabetes and habits like smoking should be carefully assessed and might contraindicate the therapy.

Chapter two

Discussion

The MARPE appliances transmit expansion force into the palatine basal bone and produced a more parallel type and more consistent suture opening upon maxillary expansion, widening of surrounding craniofacial structures including the zygoma and the nasal bone, lead to larger transverse skeletal expansion while lessening dental side effects such as dental tipping, vertical alveolar bone loss, and alveolar bending [43]. Lin et al.[52] recently conducted a direct comparison of MARPE and conventional expansion (mean age 18.1±4.4 years) and found that MARPE was more orthopedically efficient and had a lower rate of dentoalveolar side effects. This initial data may be suggestive of evidence, which should be further investigated in randomized clinical trials.

The MARPE surpasses conventional RME by a significantly decreasing excessive load on the buccal periodontal ligament of teeth to which they are anchored. It also propagates less stress to the buttresses and adjacent locations in the maxillary complex compared to the conventional RPE [43].

The MARPE led to a significant long term increase in nasopharyngeal volume when compared to RPE.The radiographic findings of Carlson et al. [56] show the widening of the entire nasomaxillary complex and reaffirm the observations in previous expansion studies. . It can therefore be reasoned that the effects on the airway can be replicated in older patients with the current MARPE treatment. One notable problem caused by a nasomaxillary deficiency is mouth breathing [57], and previous studies have demonstrated that orthopedic expansion can change the breathing pattern to nasal breathing [58,59] MARPE treatment can improve the constricted airway and facilitate nasal breathing. These changes may in turn help with the long-term stability of the expansion.

A combination of MSE and Face mask can be a successful non surgical orthopaedic treatment modality for Class III adult patients as MSE disarticulates premaxillary sutures and aid in protraction of maxilla [42]. The MARPE results in greater stability, reduced relapse. Choi et al., and Park et al., reported a success rate for MARPE as 86.96% and 84.2%, respectively [48, 60]. A recent systematic review demonstrated the mean success rate of MARPE as 92.5% with mean transverse skeletal expansion of 2.33 mm and dental expansion of 6.55 mm. These results are clinically comparable to the expansion achieved by SARPE [61].

It remains unclear why few MARPE cases fail, but it is believed that differences in calcification patterns of the mid-palatal suture and craniofacial architecture (higher resistance) are contributing factors.

Conclusion

MARPE offers a reliable non-surgical solution for a transverse maxillary deficiency in adults and young adult, reducing the need for surgeries by facilitating bone and dental expansion with greater stability, safety, and fewer side effects. MARPE in adults also have an important impact on the reduction of upper airway resistance.

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